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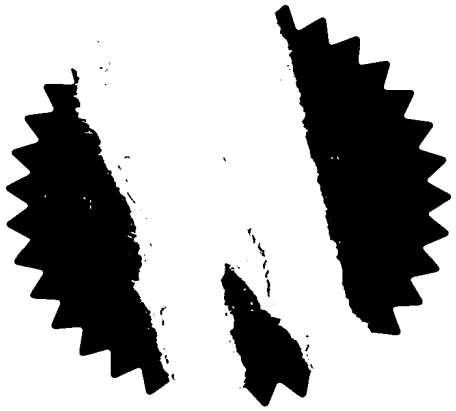

Signed A W Brewer.

Dated 12 December 2003

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1. Your reference — A10894GB - DJL

2. Patent application number *(The Patent Office will fill in this part)* — 0315419.2

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Westland Helicopters Limited
Box 255 Westland Works
Yeovil
Somerset
BA20 2YB

Patents ADP number *(if you know it)* 3978690004

If the applicant is a corporate body, give the country/state of its incorporation — United Kingdom

4. Title of the invention — Compliant Spacer

5. Name of your agent *(if you have one)* — Forrester Ketley & Co.

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Chamberlain House
Paradise Place
Birmingham
B3 3HP

Patents ADP number *(if you know it)* — 133005

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	7
Claim *(s)*	3
Abstract	1
Drawing *(s)*	2 + 2

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature: Forrester Ketley & Co.
Forrester Ketley & Co.

Date: 1 July 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

David Lucking
0121 236 0484

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

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b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

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DUPLICATE

PATENTS ACT 1977

DJL/A10894GB

Title: Compliant Spacer

Description of Invention

This invention relates to a compliant spacer which in use is located between two machine elements which are clamped together to provide an assembly, to maintain the clamping load in use, as the first and second machine elements of the assembly may relatively move due to mechanical e.g. vibration, and thermal effects.

There have been previous proposals for compliant spacers, but existing solutions have been found to be inadequate where the amount of compliance required is substantial for a large clamping load. Such previous proposals have included a sleeve design but this was found to be not sufficiently compliant; a conventional spring washer but this required more space than was available between the machine elements to be clamped together; and a conical washer but a conical washer was found not be able to tolerate the high stresses in the assembly.

For example in an assembly of the attachment of a helicopter main rotor head to a main gearbox, a clamping force is required between these machine elements to provide a pre-load on a bearing which permits of relative rotation between these elements. In such an application, a spacer which accommodates a deflection of 0.1mm over a 15mm spacing between the machine elements, under an axial loading of 159KN could not be accommodated by these previous proposals.

According to a first aspect of the invention we provide a compliant spacer which in use is located between two machine elements which are in use clamped together in an assembly, the spacer having a first generally planar face and a second oppositely facing generally planar face which is generally parallel to the first generally planar face, each of the first and second generally planar

faces having a plurality of raised regions, the raised regions of the first face being offset with respect to the raised regions of the second face so that as the two machine elements are clamped together with the spacer therebetween, the spacer deforms out-of-plane to maintain the clamping load in use.

Depending on the thickness of the spacer, by carefully selecting the number of raised regions on each generally planar face, the extent of the raised regions, and thus the spacing between the raised regions, a desired flexibility to maintain the clamping load in the assembly, can be achieved. Thus a spacer of a certain nominal thickness may be "tuned" for a particular application, by changing the number of, extent of and spacing between the raised regions on each of the first and second generally planar faces.

Preferably the same number of raised regions are provided on each of the first and second planar faces, the raised regions on the first face being interposed between the raised regions of the second face, for example, mid-way between the raised regions of the second face, so that in use, the spacer deforms out-of-plane generally constantly along the spacer. Preferably more than two raised regions are provided on each of the first and second planar faces, and more preferably more than five.

The spacer may in one example be generally annular, the first and second planar faces facing axially of the spacer. Thus each raised region may extend circumferentially around the axis of the spacer.

In one example, each raised region may extend circumferentially of the annular spacer for between 3° and 12° around the annulus, and preferably in the order of 6°, although a greater or lesser raised region extent may be desirable to allow a maximum predetermined out-of-plane deflection whilst maintaining the clamping load.

Desirably, the raised regions each include a bearing surface which in use may engage a machine element, and edge regions where the raised region joins the planar face of the spacer. The bearing surface is preferably generally flat,

but may be slightly crowned, but in each case the bearing surface is generally parallel to the first and second planar faces, and desirably at the edge regions, the raised regions meld smoothly into the planar face without any sharp discontinuity which could mark an adjacent machine element when the clamping force is applied.

The raised regions on each planar face preferably each extend outwardly of the respective planar face by between 2% and 10% of the nominal thickness of the spacer between the planar faces, and more preferably about 3%-5% of the nominal thickness between the planar faces, although the actual outward extent of the raised regions may be selected for the nominal thickness of the spacer and material from which the thickness is made, to achieve a desired resistance to out-of-plane deformation as the clamping load is applied.

Typically the nominal thickness of the spacer may be about 15mm although where a greater space between the machine elements is to be filled, the assembly may include a plurality of spacers in accordance with the first aspect of the invention, arranged in a stack.

According to a second aspect of the invention we provide an assembly of first and second machine elements which in use are clamped together with a spacer in accordance with the first aspect of the invention, therebetween.

The assembly may in one example only include a first machine element which is part of a rotor head of a helicopter rotor system, and the second machine element is part of a gearbox of the helicopter, the assembly including a bearing which permits of relative rotation between the first and second machine elements, the spacer permitting the first and second machine elements to be clamped together to provide a loading force on the bearing.

Embodiments of the invention will now be described with reference to the accompanying drawings in which:-

FIGURE 1 is an illustrative cross sectional view of part of an assembly of machine elements incorporating a compliant spacer in accordance with the invention;

FIGURE 2 is a perspective illustrative view to an enlarged scale of the compliant spacer of the assembly of figure 1.

Referring to the drawings, an assembly 10 includes a first machine element 11 which in this example is an output shaft of a gearbox in a helicopter, and a second machine element 12 which in this example is a part of a rotor head of the helicopter main rotor system.

Between the first and second machine elements 11, 12, there is a bearing 14 which permits of relative rotation between the first and second machine elements. The machine elements 11, 12 are clamped together as a plurality of fasteners (not shown) around an axis of rotation A are tightened into receiving openings 16. In a space 18 between the machine elements 11, 12 is a compliant spacer 20 which in this example is annular in configuration, and centred on the axis of rotation A.

As the clamping force is applied between the first and second machine elements 11, 12, the loading force is applied to the bearing 14. The compliant spacer 20 maintains the clamping force generally constant when movements between the first and second machine elements 11, 12 due to vibration, or thermal effects, may change the spacing between the machine elements 11, 12.

Referring particularly to figure 2, the spacer includes a first, axially facing, generally planar surface 22, and a second, oppositely axially facing, generally planar surface 23, the first and second planar surfaces 22, 23 lying generally parallel to one another.

The first planar surface 22 has a first set of raised regions, in this example, ten raised regions 25, each of which extends around the circumferential extent of the annular spacer 20, for about 6°, but this extent may be varied, for example to between 3° and 12° or more or less, depending

may be varied, for example to between 3° and 12° or more or less, depending on the amount of compliance required for a particular application, and other manufacturing configurations, as will be discussed below.

Thus the raised regions 25 of the first set are generally equally spaced around the circumferential extent of the annular spacer 20, with there being spaces 26 between adjacent pairs of raised regions 25.

The second planar face 23 has a second set of raised regions 28, which are similar in configuration to the raised regions 25 of the first set, and are equal in number. The raised regions 28 of the second set are each positioned in a space 26 between a pair of the raised regions 25 of the first set, and desirably, generally centrally between the pair of raised regions 25 of the first set.

The raised regions 25, 28 of the first and second sets, in this example, are generally identically configured, each having a bearing surface 30, and edge regions 31, 32. The edge regions 31, 32 are smooth so that there is no discontinuity as may be provided by a sharp edge, and thus the bearing surfaces 30 meld into the adjacent planar face 22, 23.

Desirably, the top/bottom bearing surfaces 30 of the raised regions 25, 28 are slightly crowned i.e. the bearing surface 30 edges adjacent the edge region, 32 may be machined slightly lower than central areas of the bearing surfaces 30, so that when the spacer 20 is loaded, the bearing surface 30 will be flat.

With the spacer 20 in place, as a clamping force is applied between the first and second machine elements 11, 12, the spacer will be deformed out-of-plane between the alternate raised regions 25, 28 of the first and second sets by an amount determined by the clamping force on the one hand, and the combination of the resilience of the material from which the spacer 20 is made, the number of and spacing of the raised regions 25, 28, and the extent of the raised regions 25, 28, out-of-plane. Generally the thinner axially the spacer 20, the more deformation will be possible, and the greater the spacing between the

raised regions 25, 28 of the first and second sets, the more deformation will be possible.

Also, the less the extent of the raised regions 25, 25 circumferentially of the spacer 20, the greater the permitted deformation.

Thus the spacer 20 may be "tuned" to allow a maximum deformation out-of-plane whilst maintaining a predetermined resistance to the clamping force applied, so that the spacer 20 can maintain the clamping force constant irrespective of small movements between the machine elements 11, 12.

In the example described, the nominal thickness of the spacer 20 between the first and second planar faces 22, 23 may be about 15mm, and the raised regions 25, 28 of each of the first and second sets, may extend outwardly of the respective planar face 22, 23 axially of the spacer 20, by about 0.5mm. The spacer 20 be made from steel, and with the ten raised regions 25, 28 in each of the first and second sets, the spacer 20 may permit of a maximum out-of-plane deformation of about 0.1mm, so that movements between the first and second machine elements 11, 12 may occur, whilst a generally constant clamping force, to maintain the pre-loading on the bearing 14, may be maintained.

Various modifications may be made without departing from the scope of the invention.

For example, as discussed above, the configuration of the spacer 20 may be changed to alter the maximum deformation provided for, and the resilience of the spacer 20. The spacer may in another assembly 10 not be annular in configuration, but may be of another shape having opposed planar faces 22, 23 with respective raised regions 25, 28.

The raised regions 25, 28 on the respective planar faces 22, 23 need not be identical in number or configuration.

Where the space 18 to be filled, between the first and second machine elements 11, 12 is greater than can be accommodated by a single spacer 20, if

desired more than one, e.g. a stack of spacers 20 may be provided, which together are configured to comply as required as the distance between the two machine elements 11, 12 may change in use.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS

1. A compliant spacer which in use is located between two machine elements which are in use clamped together in an assembly, the spacer having a first generally planar face and a second oppositely facing generally planar face which is generally parallel to the first generally planar face, each of the first and second generally planar faces each having a plurality of raised regions, the raised regions of the first face being offset with respect to the raised regions of the second face so that as the two machine elements are clamped together with the spacer therebetween, the spacer deforms out of plane to maintain the clamping load in use.

2. A spacer according to claim 1 wherein the same number of raised regions are provided on each of the first and second planar faces, the raised regions on the first face being interposed between the raised regions of the second face.

3. A spacer according to claim 2 wherein the raised regions of the first planar face are mid-way between the raised regions of the second face.

4. A spacer according to any one of the preceding claims wherein more than two raised regions are provided on each of the first and second faces, and preferably, more than five.

5. A spacer according to any one of the preceding claims wherein the spacer is generally annular, the first and second planar faces facing axially of the spacer.

6. A spacer according to claim 5 wherein each raised region extends circumferentially around the axis of the spacer.

7. A spacer according to claim 6 wherein each raised region extends circumferentially of the annular spacer for between 3° and 12° around the annulus, and preferably in the order of 6°.

8. A spacer according to any one of the preceding claims wherein the raised regions each include a bearing surface and edge regions where the raised region joins the planar face of the spacer.

9. A spacer according to claim 8 wherein the bearing surface is generally parallel to the first and second planar faces, and at the edge regions, the raised regions meld smoothly into the planar face without any sharp discontinuity.

10. A spacer according to any one of the preceding claims wherein the raised regions on each planar face each extend outwardly of the respective planar face by between 2% and 5% of the nominal thickness of the spacer between the planar faces.

11. A spacer according to claim 10 wherein the raised regions on each planar face each extend outwardly of the respective planar face by about 3% of the nominal thickness of the spacer between the planar faces.

12. A spacer according to any one of the preceding claims wherein the nominal thickness of the spacer between the planar faces is about 15mm.

12. A spacer substantially as hereinbefore described with reference to and/or as shown in figure 1 of the accompanying drawings.

13. An assembly of first and second machine elements which in use are clamped together with a spacer in accordance with any one of the preceding claims, therebetween.

14. An assembly according to claim 13 wherein the first machine element is a part of a rotor head of a helicopter rotor system, and the second machine element is part of a gearbox of the helicopter, the assembly including a bearing which permits of relative rotation between the first and second machine elements, the spacer permitting the first and second machine elements to be clamped together to provide a loading force on the bearing.

15. An assembly substantially as hereinbefore described with reference to and/or as shown in figure 1 of the accompanying drawings.

16. Any novel feature of novel combination of features described herein and/or as shown in the accompanying drawings.

ABSTRACT

Title: Compliant Spacer

A compliant spacer 20 which in use is located between two machine elements 11, 12 which are in use clamped together in an assembly 10, has a first generally planar face 22 and a second oppositely facing generally planar face 23 which is generally parallel to the first generally planar face 22, each of the first and second generally planar faces 22, 23 each having a plurality of raised regions 25, 28, the raised regions 25 of the first face 22 being offset with respect to the raised regions 28 of the second face 23 so that as the two machine elements 11, 12 are clamped together with the spacer 20 therebetween, the spacer 20 deforms out of plane to maintain the clamping load in use.

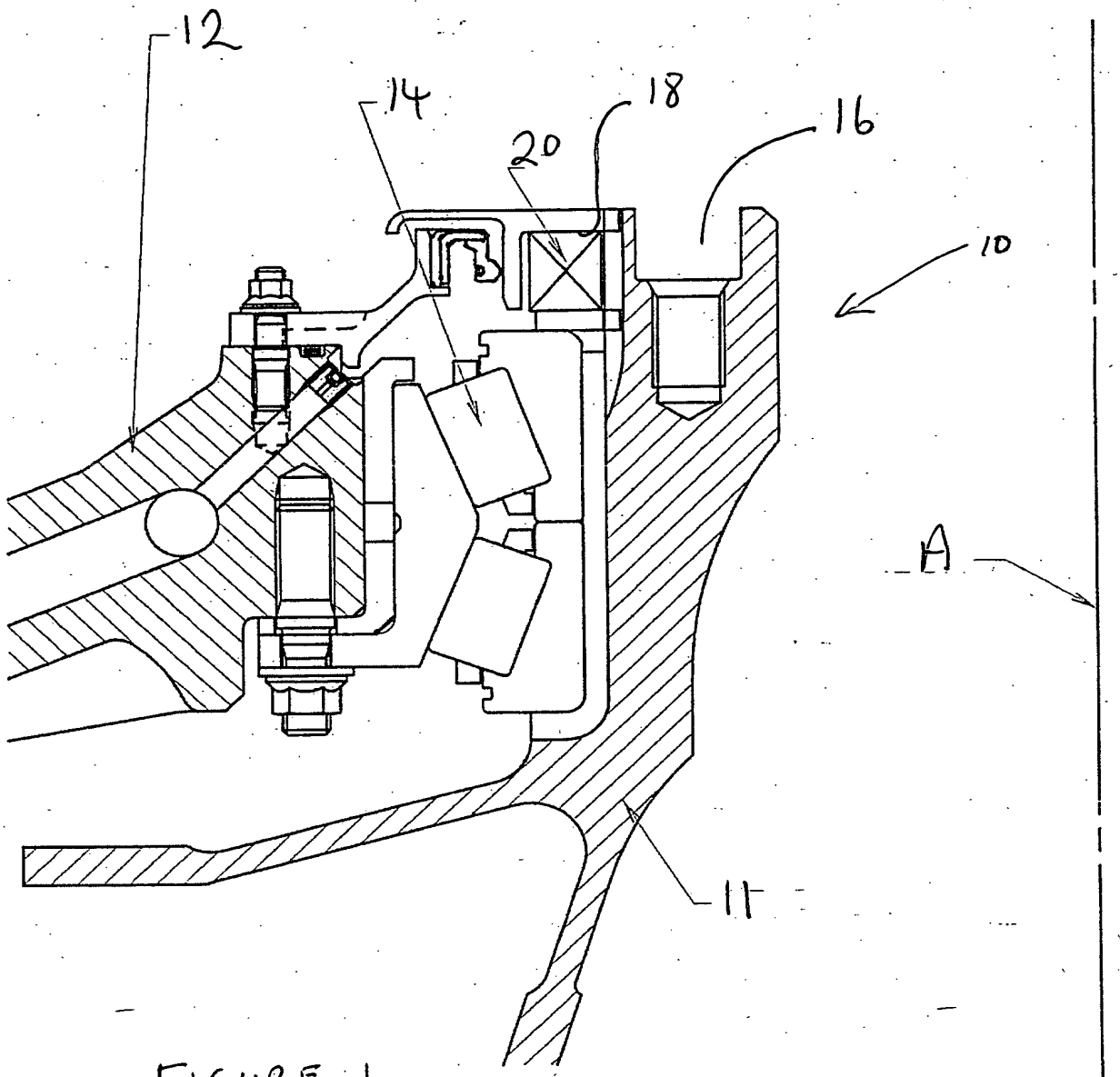

FIGURE 1

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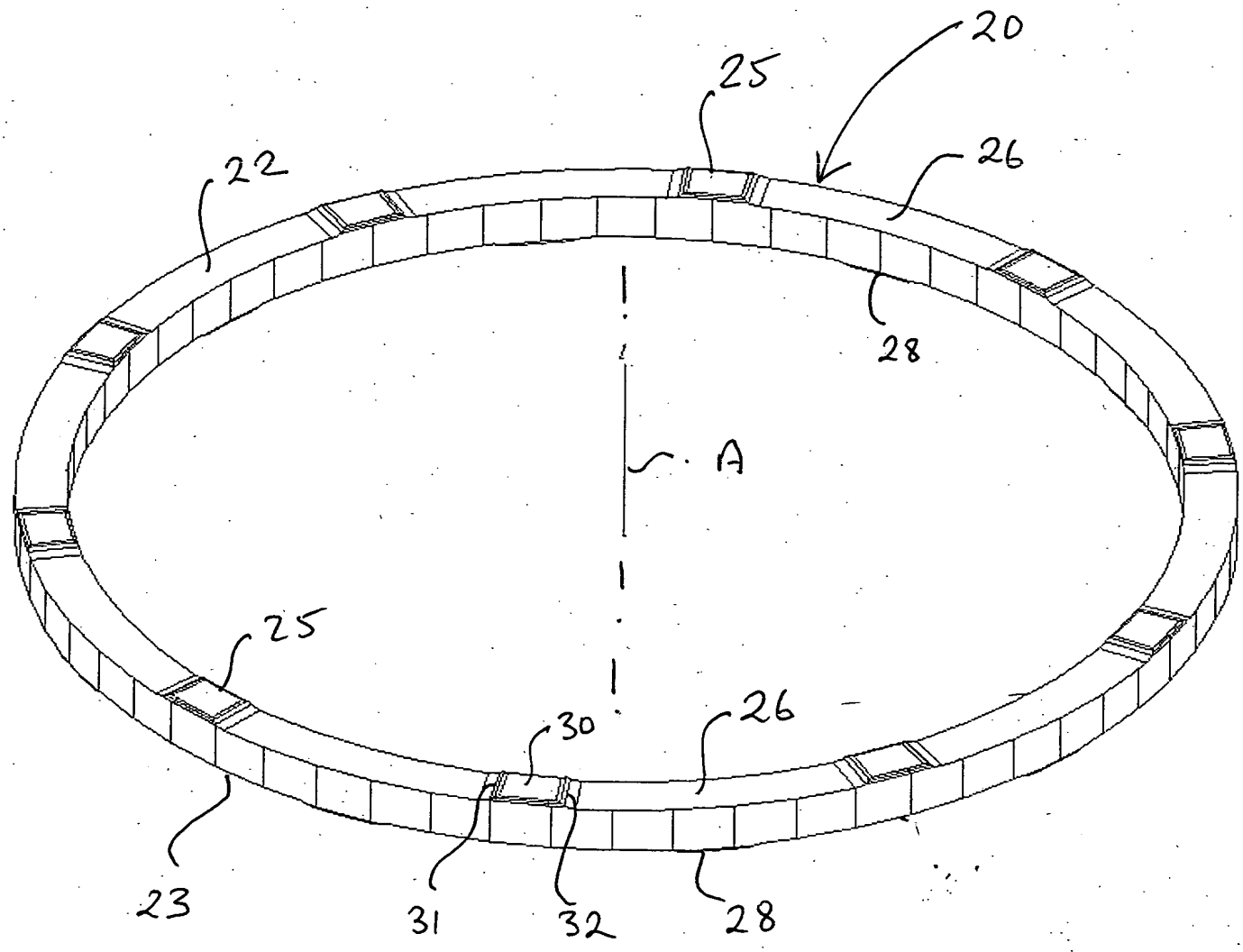
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